REPORT DOCUMENTATIC

AD-A232 075

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	31December 91	Final Report

4. TITLE AND SUBTITLE

Ada Programming Support Environment(APSE) Evaluation and Validation (E&V) Team

5. FUNDING NUMBERS

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Ada Joint Program Office
The Pentagon, Rm 3E114
Washington, D.C. 20301-3080

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited Public Distribution

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report has been prepared to reflect the current state of the APSE E&V technology as developed by the E&V Project, and the recommendations of the E&V Team regarding potential future directions. The E&V Team has completed its charter and has prepared this report for reader consideration. The final team recommendations are given in Section 4.

14. SUBJECT TERMS

Evaluation and Validation (E&V)
Ada Compiler Evaluation Capability (ACEC)

15. NUMBER OF PAGES

25

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

GENERAL INSTRUCTIONS FOR COMPLETING SF 298

The Report Documentation Page (RDP) is used in announcing and cataloging reports. It is important that this information be consistent with the rest of the report, particularly the cover and title page. Instructions for filling in each block of the form follow. It is important to stay within the lines to meet optical scanning requirements.

Block 1. Agency Use Only (Leave blank).

Block 2. Report Date. Full publication date including day, month, and year, if available (e.g. 1 Jan 88). Must cite at least the year.

Block 3. Type of Report and Dates Covered. State whether report is interim, final, etc. If applicable, enter inclusive report dates (e.g. 10 Jun 87 - 30 Jun 88).

Block 4. Title and Subtitle. A title is taken from the part of the report that provides the most meaningful and complete information. When a report is prepared in more than one volume, repeat the primary title, add volume number, and include subtitle for the specific volume. On classified documents enter the title classification in parentheses.

Block 5. Funding Numbers. To include contract and grant numbers; may include program element number(s), project number(s), task number(s), and work unit number(s). Use the following labels:

C	- Contract	**PR**	- Project
G	- Grant	**TA**	- Task
PE	- Program Element	**WU**	- Work Unit Accession No.

Block 6. Author(s). Name(s) of person(s) responsible for writing the report, performing the research, or credited with the content of the report. If editor or compiler, this should follow the name(s).

Block 7. Performing Organization Name(s) and Address(es). Self-explanatory.

Block 8. Performing Organization Report Number. Enter the unique alphanumeric report number(s) assigned by the organization performing the report.

Block 9. Sponsoring/Monitoring Agency Name(s) and Address(es). Self-explanatory.

Block 10. Sponsoring/Monitoring Agency Report Number. (If known)

Block 11. Supplementary Notes. Enter information not included elsewhere such as: Prepared in cooperation with...; Trans. of...; To be published in.... When a report is revised, include a statement whether the new report supersedes or supplements the older report.

Block 12a. Distribution/Availability Statement. Denotes public availability or limitations. Cite any availability to the public. Enter additional limitations or special markings in all capitals (e.g. NOFORN, REL, ITAR).

DOD - See DoDD 5230.24, "Distribution Statements on Technical Documents."
DOE - See authorities.
NASA - See Handbook NHB 2200.2.
NTIS - Leave blank.

Block 12b. Distribution Code.

DOD - DOD - Leave blank.
DOE - DOE - Enter DOE distribution categories from the Standard Distribution for Unclassified Scientific and Technical Reports.
NASA - NASA - Leave blank.
NTIS - NTIS - Leave blank.

Block 13. Abstract. Include a brief (Maximum 200 words) factual summary of the most significant information contained in the report.

Block 14. Subject Terms. Keywords or phrases identifying major subjects in the report.

Block 15. Number of Pages. Enter the total number of pages.

Block 16. Price Code. Enter appropriate price code (NTIS only).

Blocks 17. - 19. Security Classifications. Self-explanatory. Enter U.S. Security Classification in accordance with U.S. Security Regulations (i.e., UNCLASSIFIED). If form contains classified information, stamp classification on the top and bottom of the page.

Block 20. Limitation of Abstract. This block must be completed to assign a limitation to the abstract. Enter either UL (unlimited) or SAR (same as report). An entry in this block is necessary if the abstract is to be limited. If blank, the abstract is assumed to be unlimited.

EXECUTIVE SUMMARY

The E&V Project and the E&V Team were formed in 1983. The purpose of the project was to provide a capability to assess APSEs and to determine conformance of APSEs to applicable standards. The purpose of the team was to assist the project in several ways. Raymond Szymanski of Wright Research and Development Center (WRDC, now Wright Laboratory, WL) served as project and team leader from 1985 until the completion of team activities, and brought continuity that provided a setting for productive contractual efforts and coordinated team products*.

The principal products of the contractual efforts are: a test suite known as the Ada Compiler Evaluation Capability (ACEC), a pair of documents known as the E&V Reference System, and a test suite known as the CAIS Implementation Validation Capability (CIVC). The E&V Team held quarterly meetings that produced many suggestions and a number of documents which had a significant influence on the contractor-developed products. A report from the team chairman summarizing the team's purpose, process, and products, as well as his personal prognosis and recommendations is included in this report (Section 2). He concludes that considerable work is still required to enable DoD to derive full benefit from the E&V effort, and recommends specific steps to transition and use DoD-developed E&V technology and to promote the development of additional E&V technology. Summary reports from each of the team's working groups are also included (Section 3). The list below summarizes the team's recommendations concerning future use and development of E&V technology. A more complete statement is provided in Section 4.

E&V Team Recommendations

1. Raise public awareness of E&V and, as a broad objective, encourage use of APSE E&V technology
2. Mandate compiler evaluations
3. Create a Quality Testing Center Of Expertise
4. Continue development of E&V technology in four areas and coordination with related activities
5. Promote applicable APSE standards
6. Identify an appropriate organization for APSE E&V standards activities; develop, manage, and maintain E&V test suites using a unified approach
7. Promote international sharing of E&V technology, but avoid joint multinational development of assessor products.

*Virginia Castor served as project and team leader from December 1983 to June 1985.

TABLE OF CONTENTS

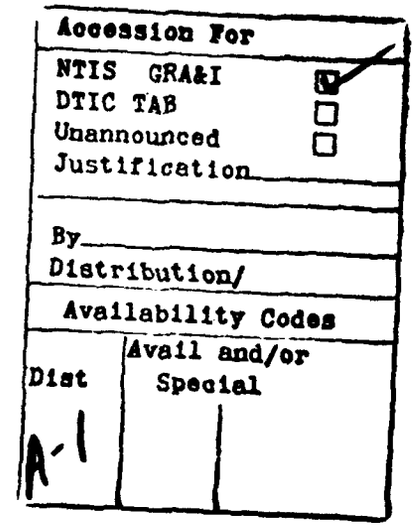
		Page
EXECUTIVE SUMMARY		ES–1
LIST OF FIGURES		iv
1.	INTRODUCTION	1–1
1.1	Purpose of this Document	1–1
1.2	Background	1–1
1.3	Team Organization	1–2
1.4	Document Organization	1–3
2.	REPORT OF THE E&V CHAIRMAN TO THE AJPO	2–1
2.1	The Purpose of the E&V Team	2–1
2.2	The Process	2–2
2.3	The Products — Produced by the E&V Team	2–2
2.3.1	Requirements Document [E&V Requirements 1987]	2–2
2.3.2	Component Validation Procedures Document [CVP 1985]	2–2
2.3.3	Issues and Strategies for CAIS Evaluation and Validation [Issues 1987]	2–3
2.3.4	*Issues and Strategies* for Evaluation and Validation of CAIS-A Implementations [Issues 1990]	2–3
2.3.5	Tools and Aids Document [E&V Tools and Aids 1990]	2–3
2.4	The Products — With the E&V Team as Technical Contributors	2–3
2.4.1	Ada Compiler Evaluation Capability (ACEC)	2–3
2.4.2	CAIS Implementation Validation Capability (CIVC)	2–5
2.4.3	Evaluation and Validation Reference System	2–7
2.5	The Prognosis	2–9
3.	WORKING GROUP REPORTS	3–1
3.1	Ada Compiler Evaluation Capability Working Group (ACECWG)	3–1
3.1.1	ACECWG Purpose	3–1
3.1.2	ACECWG Major Products	3–1
3.1.3	ACECWG Activities	3–1
3.1.4	ACECWG Recommendations	3–2
3.2	CAIS Implementation Validation Capability Working Group (CIVCWG)	3–2
3.2.1	CIVCWG Purpose	3–2
3.2.2	CIVCWG Major Products	3–3
3.2.3	CIVCWG Activities	3–3
3.2.4	CIVCWG Recommendations	3–3
3.3	Classification Working Group (CLASSWG)	3–4
3.3.1	CLASSWG Purpose	3–4
3.3.2	CLASSWG Major Products	3–4
3.3.3	CLASSWG Activities	3–4
3.3.4	CLASSWG Recommendations	3–4
3.4	Requirements Working Group (REQWG)	3–5
3.4.1	REQWG Purpose	3–5
3.4.2	REQWG Major Products	3–5

TABLE OF CONTENTS (Continued)

		Page
3.4.3	REQWG Activities	3–5
3.4.4	REQWG Recommendations	3–5
3.5	Standards Evaluation and Validation Working Group (SEVWG)	3–6
3.5.1	SEVWG Purpose	3–6
3.5.2	SEVWG Major Products	3–6
3.5.3	SEVWG Activities	3–6
3.5.4	SEVWG Recommendations	3–6
4.	RECOMMENDATIONS	4–1
4.1	Raise Public Awareness of E&V and, as a Broad Objective, Encourage Use of APSE E&V Technology	4–1
4.2	Mandate Compiler Evaluations	4–4
4.3	Create a Quality Testing Center of Expertise	4–5
4.4	Continue Development of E&V Technology in Four Areas and Coordination With Related Activities	4–6
4.5	Promote Applicable APSE Standards	4–8
4.6	Identify an Appropriate Organization for E&V of APSE Standards Activities; Develop, Manage, and Maintain E&V Test Suites Using a Unified Approach	4–9
4.7	Promote International Sharing of E&V Technology, But Avoid Joint Multinational Development Of Assessor Products	4–11
5.	CONCLUSION	5–1
APPENDIX A	LIST OF ACRONYMS	A–1
APPENDIX B	E&V TEAM PARTICIPANTS	B–1
APPENDIX C	REFERENCES	C–1

LIST OF FIGURES

Figure		Page
2.1-1	The Role of E&V Technology	2–1
2.4.3-1	The E&V Reference System	2–8



1. INTRODUCTION

1.1 PURPOSE OF THIS DOCUMENT

This report has been prepared to reflect the current state of Ada Programming Support Environment (APSE) Evaluation and Validation (E&V) technology as developed by the E&V Project, and the recommendations of the E&V Team regarding potential future directions. The E&V Team has completed its charter and has prepared this report for reader consideration. The final team recommendations are given in Section 4. This report does not necessarily reflect the opinion of the Ada Joint Program Office (AJPO), the U.S. Air Force, or the Wright Research and Development Center (WRDC). Rather, it represents the participants' perspectives regarding future directions for the E&V Reference System, the Ada Compiler Evaluation Capability (ACEC), the Common APSE Interface Set (CAIS) Implementation Validation Capability (CIVC), and APSE E&V, in general.

1.2 BACKGROUND

The AJPO was formed in December 1980 by the Under Secretary of Defense for Research and Engineering to manage the efforts related to the introduction, implementation, and life cycle support of the Ada programming language. One of these efforts is the development of APSE E&V technology. The AJPO is responsible for ensuring that the Department of Defense (DoD) has the programming support tools needed to develop and support defense systems software written in the Ada language, and that these tools conform to DoD standards.

In June 1983, the AJPO proposed the formation of the E&V Project and a tri-service APSE E&V Team with the Air Force designated as lead service. In October 1983, the Air Force officially accepted responsibility as lead service on the E&V Project with the Air Force Wright Aeronautical Laboratory (AFWAL, now known as the Wright Research and Development Center) as the lead organization and the Avionics Laboratory as the lead laboratory for the project. The project was tasked with the following: (1) identifying and defining specific E&V technology requirements, (2) developing selected elements of the required technology, (3) encouraging others to develop additional elements, and (4) collecting information describing existing elements.

1.3 TEAM ORGANIZATION

The project's technical team was formed in December 1983 and was designated the E&V Team. The E&V Team was charged with the responsibility of developing a variety of foundation documents and providing technical guidance early-on in the E&V Project. The E&V Team was a DoD team with members from the three services and other DoD agencies.

In April 1984, following a precedent set by another DoD tri-service team, the KAPSE Interface Team (KIT), the E&V Project invited several representatives from industry and academia to participate in a workshop [E&V Workshop 1984]. These representatives became Distinguished Reviewers (DRs), who continued to supplement the team knowledge base and provided the E&V Team with a broad range of inputs, reviews, and advice of the highest technical quality.

The E&V Team was initially partitioned into several working groups which produced white papers and other reports on E&V topics. The charter for each of these groups and the work they performed are recorded in a series of E&V Team Public Reports. [E&V Report 1984, 1985, 1987, 1989, 1990]. As time progressed, however, the E&V Project began to award contracts for the development of E&V technology. In order to exploit the technical expertise of the E&V Team for the benefit of the technical developments, the team was reorganized into the following six working groups:

- ACECWG — The Ada Compiler Evaluation Capability (ACEC) Working Group was responsible for providing technical inputs to the ACEC product.
- CIVCWG — The CAIS Implementation Validation Capability (CIVC) Working Group was responsible for providing technical inputs to the CIVC product.
- CLASSWG — The Classification Working Group was responsible for providing technical inputs to the E&V Reference System documents.
- PUBWG — The Publicity Working Group was responsible for assisting in the development and review of E&V Project publicity information and E&V Team Public Reports. (This group later merged into the REQWG; therefore, there is no PUBWG report in this document.)
- REQWG — The Requirements Working Group was responsible for E&V Project requirements.
- SEVWG — The Standards Evaluation and Validation Working Group was responsible for reviewing APSE related standards such as MIL-STD-1838A, the CAIS-A standard, [DoD 1989] to identify E&V technology needs.

These groups worked together to ensure that the E&V Project developments met the needs of the DoD user community. The accomplishments and successes of these working groups are detailed in upcoming sections.

1.4 DOCUMENT ORGANIZATION

Section 1 — Introduction, provides the purpose of this report as well as background for the existence of the E&V Team and its associated working groups.

Section 2 — Report of the E&V Team Chairman to the AJPO, presents a summary of the E&V Team activities and products since the team's inception in December 1983, and the chairman's prognosis and recommendations.

Section 3 — Working Group Reports, presents the final reports of the working groups along with recommendations specific to individual working groups.

Section 4 — Recommendations, presents the major recommendations of the E&V Team.

Section 5 — Conclusion, provides a brief concluding statement.

Appendices A, B, and C define acronyms, list team participants, and cite references, respectively.

2. REPORT OF THE E&V CHAIRMAN TO THE AJPO

2.1 THE PURPOSE OF THE E&V TEAM

In October 1983, the Air Force officially accepted responsibility as lead service on the E&V Project. The purpose of the E&V Project was to provide a capability to assess APSEs and to determine conformance of APSEs to applicable standards. Figure 2.1-1 provides a pictorial view of the intended role of E&V technology in DoD system developments. The E&V Team was formed to assist the E&V Project as follows:

- Develop an E&V Requirements Document against which E&V Project products and Team activities could be assessed.
- Provide recommendations for development/acquisition of E&V tools/aids through the development of an E&V Tools and Aids document.
- Provide technical guidance in early stages of E&V Project product developments.

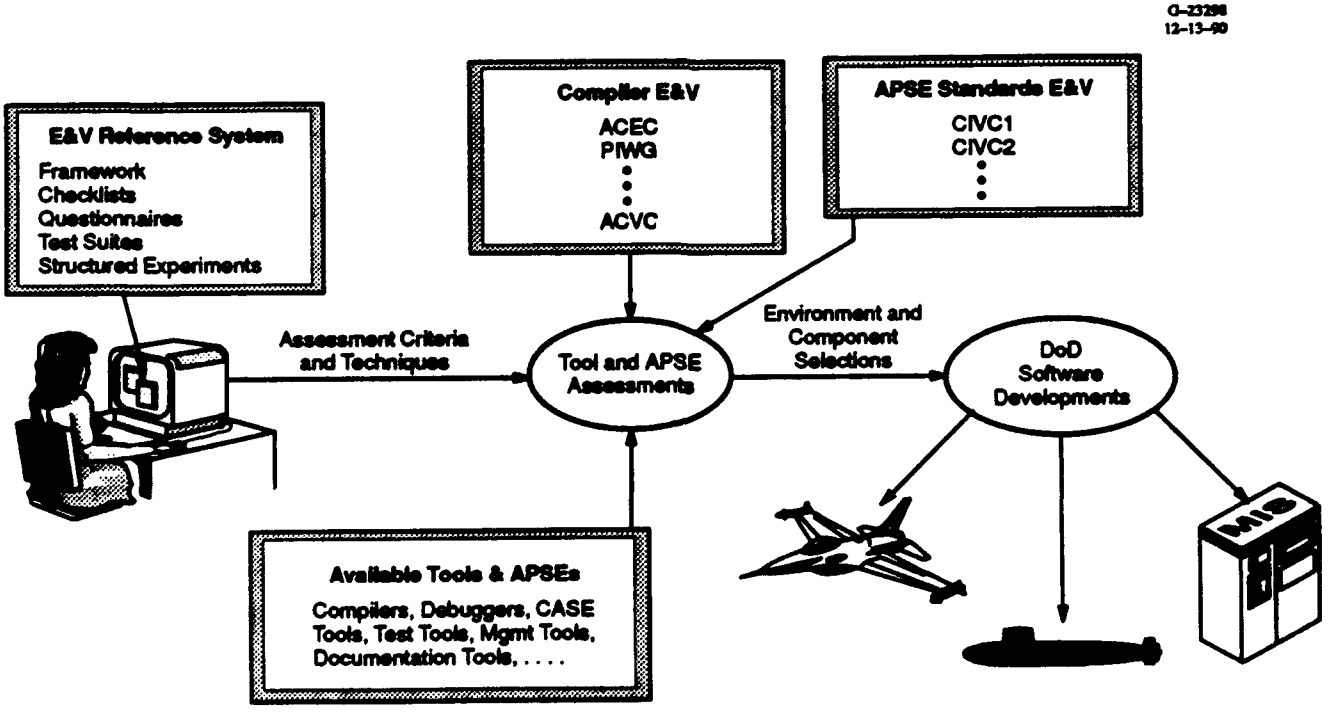


Figure 2.1-1 The Role of E&V Technology

The E&V Requirements Document, the E&V Tools and Aids Document, and the Issues and Strategies for CAIS Evaluation and Validation Document have all been completed [E&V Requirements 1987] [E&V Tools and Aids 1990] [Issues 1990]. Additionally, each of the E&V Project product developments has produced, as a minimum, two versions of their respective products (E&V Reference System, ACEC, and CIVC). These products were substantially influenced by the E&V Team.

2.2 THE PROCESS

The E&V Team met quarterly from December 1983 through September 1990 for a total of 28 meetings. The results of these meetings are a number of E&V technology developments which are in use today by the DoD. Although the E&V Project can be considered successful for its present accomplishments, *considerable work is still required to enable the DoD to derive full benefit from the E&V effort.*

Now that the work of the E&V Team has reached completion, it is time to consider the future of E&V technology. As reflected in the recommendations that follow, there is a need to enhance the existing E&V Project products and to undertake new E&V technology developments. Additionally, the DoD should take steps to encourage the use of available E&V technology. This encouragement could be manifested through changes in acquisition policy which would require the use of E&V technology prior to acquisition of critical software tools. Finally, the team believes that "centers of expertise" should be established by the DoD for the application, enhancement, and development of E&V technology.

2.3 THE PRODUCTS — PRODUCED BY THE E&V TEAM

2.3.1 Requirements Document [E&V Requirements 1987]

This document sets forth the requirements on the E&V Project. It was intended for use by the E&V Team when determining which activities to pursue and by the support contractors when developing technology for the E&V Project.

2.3.2 Component Validation Procedures Document [CVP 1985]

This document examined procedures for validating APSE components for which a standard exists. It proposed a process for assuring consistent implementations of the CAIS through administration of a validation capability that is similar to the procedures adopted for Ada language validation.

2.3.3 Issues and Strategies for CAIS Evaluation and Validation [Issues 1987]

This document was developed during the later phases of the DoD-STD-1838 (CAIS) development cycle and it made significant recommendations for modifications to the proposed CAIS standard. One particular recommendation included the addition of a package to facilitate validation test suites and automatic adaptation of tools. Other recommendations focused on improvements to the readability and understandability of the document defining the standard.

2.3.4 Issues and Strategies for Evaluation and Validation of CAIS-A Implementations [Issues 1990]

Based on the CAIS-A standard (MIL-STD-1838A) and results of the CIVC project, this document covers topics relevant to creating a validation mechanism for CAIS-A. The document raises issues relating to cost, test selection criteria, maintenance of the validation suite, and tools to aid in construction of the validation suite. Recommendations contained in the document suggest ways to resolve the issues discussed.

2.3.5 Tools and Aids Document [E&V Tools and Aids 1990]

This document includes recommendations for specific elements of E&V technology which need to be developed, and an accompanying prioritization of their implementation order. Appendices of the Tools and Aids Document provide detailed specifications for selected recommended elements.

2.4 THE PRODUCTS — WITH THE E&V TEAM AS TECHNICAL CONTRIBUTORS

2.4.1 Ada Compiler Evaluation Capability (ACEC)

The Ada Compiler Evaluation Capability (ACEC) is being developed by Boeing Military Airplane under contract to the Air Force Wright Research and Development Center (WRDC) with funding from the AJPO. Its primary purpose is to provide the capability to determine the performance and usability characteristics of Ada compilation systems. The ACEC consists of the ACEC Software Product and three supporting documents: the ACEC User's Guide, the ACEC Reader's Guide, and the ACEC Version Description Document [ACEC 1990] [ACEC 1990a] [ACEC 1990b].

2.4.1.1 ACEC Software Product — The ACEC Software Product consists of performance tests, assessor tools, and support software. The software product makes it possible to:

- Compare the performance of several implementations.
- Isolate the strong and weak points of a specific system, relative to other systems which have been tested.

- Determine what significant changes were made between releases of a compilation system.
- Predict performance of alternative coding styles.
- Evaluate the clarity and accuracy of a system's diagnostic messages.
- Determine whether the functional capabilities of a program library system are sufficient to accomplish a set of predefined scenarios.
- Determine whether the functional capabilities of a symbolic debugger are sufficient to accomplish a set of predefined scenarios.

The ACEC performance tests provide assistance in measuring execution time efficiency, code size efficiency, and compile time efficiency. The assessor tools provide assistance in evaluating symbolic debuggers, program library systems, and compiler diagnostics. The test suite does not include explicit tests for the existence of language features.

The support software is a set of tools and procedures which assist in preparing and executing the test suite, in extracting data from the results of executing the test suite, and in analyzing the performance measurements obtained. The support tools consist of:

- INCLUDE — assists in adapting programs to particular targets by performing source text inclusion.
- FORMAT and MED_DATA_CONSTRUCTOR — extract and format timing and code expansion data.
- MEDIAN — compares results of performance tests of various systems.
- SINGLE SYSTEM ANALYSIS — compares results of related tests from a single system.

The ACEC Software Product was developed for a variety of targets and is distributed on one 9-track, 1600 bpi, VAX/VMS backup tape containing approximately 20 megabytes of data.

2.4.1.2 ACEC Documentation Products — The ACEC Documentation Products are as follows:

- ACEC User's Guide — The ACEC User's Guide [ACEC 1990a] provides ACEC users with the information necessary to adapt and execute the ACEC Software Product. This guide explains how to use the support tools and how to deal with the problems which may occur in the process of adapting and executing the ACEC Software Product.
- ACEC Reader's Guide — The ACEC Reader's Guide [ACEC 1990] describes how users can interpret the results of executing the performance tests and assessor tools.

This guide also discusses the statistical significance of the numbers produced, the organization of the test suite, and the submission of error reports and change requests.

- ACEC Version Description Document — The Version Description Document [ACEC 1990b] describes the ACEC Software Product as contained on the distribution tape, including the compilation units, programs, test problems, and sample data. This document also contains a set of indexes which allow the user to identify each test, its primary purpose, its secondary and incidental purposes, related and comparison test problems, and applicable Ada Language Reference Manual [DoD 1983] sections.

2.4.2 CAIS Implementation Validation Capability (CIVC)

The CAIS Implementation Validation Capability (CIVC) is being developed by SofTech under contract to the Air Force Wright Research and Development Center (WRDC) with funding from the AJPO. The CIVC effort is developing a validation test suite to assess conformance of CAIS implementations to MIL-STD-1838A [DoD 1989]. The CAIS is an extensive set of interfaces designed to support the development of portable tools for use in APSEs. The CIVC has successfully applied information modeling to the test coverage design and assessment required for validation testing. Hypermedia has been used for the delivery of test requirements, test designs, and their associated traceability relationships. Version 1 of the CIVC (CIVC1) was delivered in February 1990, and assesses conformance to DoD-STD-1838 [DoD 1986]. Version 2 of the CIVC (CIVC2) is being prepared for delivery in February 1992, and will be used to assess conformance to MIL-STD-1838A.

2.4.2.1 CIVC Software Products — The software components of the CIVC are the Framework, the Test Administrator, and the Test Suite. Each of these components is briefly described below.

- CIVC1 Framework — The CIVC1 Framework is a hypertext-based product that provides complete and unique traceability between DoD-STD-1838 and the CIVC1 software product. The Framework product provides the means for evaluating the correctness of both the CIVC1 product and proposed additions to the test suite. See [CIVC 1990].
- Test Administrator — The Test Administrator provides the CIVC1 and CIVC2 Beta release user interfaces, encapsulates any target environment dependencies for operating these suites, and schedules and executes the CIVC1 and CIVC2 validation tests defined in the Test Suite. See [CIVC 1990a].
- CIVC1 Test Suite — Test objectives, scenarios, test cases, static compilation tests, and a report manager constitute the CIVC1 Test Suite. The Test Suite encapsulates the actual tests which exercise a CAIS implementation and is organized by superclasses. Superclasses are arbitrary organizations of test classes. Test classes are groups of test cases which either have similar preconditions, or have preconditions which depend on the postcondition of a previously executed test case.

- CIVC2 Beta Test Suite — A preliminary validation capability of MIL-STD-1838A was delivered in July 1990 as the CIVC2 Beta Test Suite. Derived from the CIVC1 Test Suite, 147 test cases were modified to exercise the CAIS-A interfaces.
- CIVC2 Framework — To support the evaluation for correctness of the CIVC2, completeness and consistency will be determined by developing a full traceability framework between the requirements of MIL-STD-1838A and the CIVC2 software product. The CIVC2 Framework will incorporate aspects of the latest hypertext technology (i.e., "sticky-text" links).
- CIVC2 Test Suite — Test objectives, scenarios, test cases, static compilation tests, and a report manager constitute the CIVC2 Test Suite. The Test Suite encapsulates the actual tests and is organized by test classes. Test selection is accomplished by automated analysis and prioritization systems. See [CIVC 1990b].

Collectively, these products (1) discover and report ambiguities, incomplete parts, and other potential impediments to common interpretations of CAIS/CAIS-A, and (2) produce mechanisms for analyzing and reporting errors in CAIS/CAIS-A implementations that violate specifications.

2.4.2.2 CIVC Documentation Products — The CIVC Documentation Products are as follows:

- CIVC1 Implementor's Guide — The CIVC1 Implementor's Guide [CIVC 1989] presents the conformance requirements (test objectives) for a CAIS implementation, as well as the top level designs (scenarios) for the test cases that will validate a CAIS implementation's conformance to DoD-STD-1838. Also included are the conventions and rationale used in the development of these CIVC1 products.
- CIVC1 Framework — The hypertext-based framework provides the traceability documentation between the DoD-STD-1838 and the CIVC1 product. See [CIVC 1990].
- Test Report Reader's Guide with Appendix 1 – Operator's Guide — [CIVC 1990a] This Technical Operating Report describes the format of the CIVC Conformance Report and how to interpret the data presented in the Conformance Report. The Operator's Guide details the system requirements, installation, and operation of CIVC1.
- CIVC2 Beta Test Suite Operator's Guide [CIVC 1990b] — This document details the host system requirements, installation, and operation of the CIVC2 beta release (CIVC-Beta). This beta release of the CIVC provides early validation support to CAIS-A implementors.

The CIVC2 documentation products corresponding to the CIVC1 documentation products above will be delivered in early 1992.

2.4.3 Evaluation and Validation Reference System

The Evaluation and Validation Reference System is being developed by TASC under contract to the Air Force Wright Research and Development Center (WRDC) with funding from the AJPO. It consists of two companion documents: the E&V Reference Manual, Version 2.0 [E&V RM 1989] and the E&V Guidebook, Version 2.0 [E&V GB 1989]. Version 3.0 of both documents will be available in early 1991.

The purpose of the E&V Reference Manual is to provide information that will help users to:

- Gain an overall understanding of APSEs and approaches to their assessment.
- Find useful reference information (e.g., definitions) about specific elements and relationships between elements.
- Find criteria and metrics for assessing tools and APSEs, and techniques for performing such assessments.

Chapters 1 through 3 provide a general introduction to the document and to the issue of assessing APSEs as a whole. Chapter 4 and later chapters each correspond to one index of an overall E&V Classification Schema. The schema adopts a relational model of the subject and process of E&V. This model allows the user to arrive at E&V techniques through many different paths, and provides a means to extract useful information along the way.

The purpose of the E&V Guidebook is to provide information that will help users to assess APSEs and APSE components by:

- Assisting in the selection of E&V procedures, the interpretation of results, and the integration of analyses and results.
- Describing E&V procedures and techniques developed by the E&V Project.
- Assisting in the location of E&V procedures and techniques developed outside the E&V Project.

All E&V procedures and techniques found in the Guidebook are referenced by the indexes contained in the E&V Reference Manual. Chapters 1 through 4 provide a general introduction to the document and other background material. Chapter 5 and later chapters each contain all the assessment procedures and techniques associated with a particular group of tools or tool sets to be assessed, such as Compilation System Assessors or Test System Assessors. The assessment procedures are described and, in some instances, can be applied directly from the information given in the Guidebook. In other cases, the user is directed to a primary reference for more information. Figure 2.4.3-1 illustrates the relationship between the Reference Manual and the Guidebook.

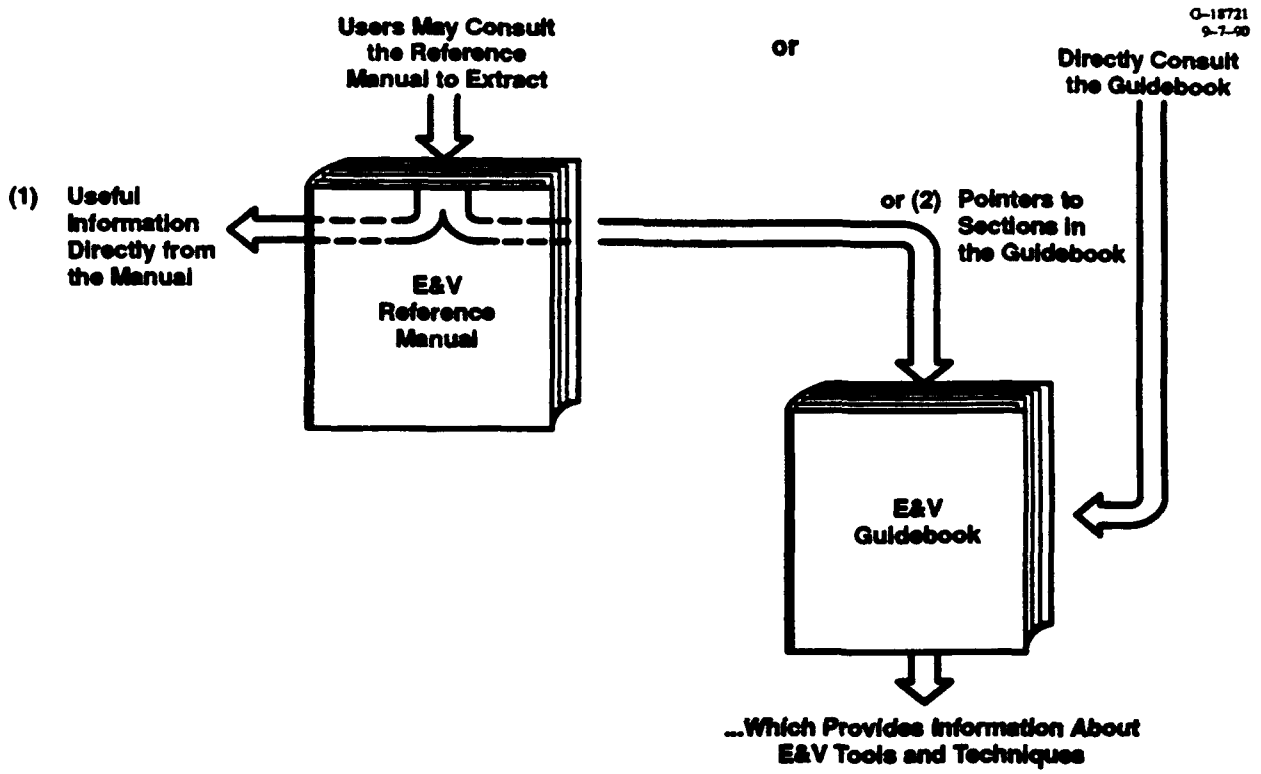


Figure 2.4.3-1 The E&V Reference System

The contractor has also begun development of a set of structured experiments designed to evaluate integrated APSEs. These are built around a "model project" testbed that has been partially designed, implemented, tested, and documented using DoD-STD-2167A [DoD 1988] formats. The initial set of experiments consist of scripted scenarios, which emphasize software testing activities. Rather than focus on the evaluation of a single test tool or function, the scenarios are designed with a "whole team" perspective and address a spectrum of activities such as test planning, documentation, unit testing, component testing, integration testing, bug fixing, regression testing, status reporting, and configuration control. The experiments are designed to provide an initial baseline that can be extended to cover other aspects of "whole APSE" performance and "whole team" support.

2.5 THE PROGNOSIS

It is my belief that the E&V Team effort has been successful. Although its activities were extremely diverse, it has produced documents which should guide the DoD in its future E&V endeavors. Additionally, the Team has made outstanding technical contributions to the E&V Project's technical developments. As a result, the list of DoD offices and DoD contractors who use E&V technology is ever growing. However, *steps must be taken to ensure the continued successful application of E&V technology and to fully exploit the effort already expended.* Specifically, the DoD must:

- Transition existing DoD-developed E&V technology to an agency where it can be maintained, matured, and made available to users.
- Promote the development of additional E&V technology (The Tools and Aids Document prioritzes and details the required technology.).
- Encourage the use of E&V technology through acquisition policy changes and the development of Government "centers of expertise."

Currently, the E&V Project is managed by the U.S. Air Force Avionics Laboratory. Although the laboratory is an excellent choice for technology development, its charter is not conducive to long term maintenance of technical products. Additionally, the laboratory infrastructure is not set up to support the widespread distribution requirements necessary for existing and future E&V technology. Therefore, *a DoD agency or agencies must be identified and agree to accept the current E&V Project developments for the purpose of maintenance, enhancement, and distribution.*

It is my belief that the E&V Project has barely scratched the surface in developing the E&V technology required by the DoD. With the availability of a document such as the Tools and Aids Document, the only other items required for developing additional E&V technology are experienced personnel and money. Therefore, it is recommended that the DoD identify an agency or agencies to continue the development of E&V technology and get that agency to commit to the process. To exploit the DoD's current experience base, *it is highly recommended that this action take place prior to the termination of the E&V Project.*

In today's shrinking DoD budget climate, we cannot afford the software development failures of the past. Many of these failures can be directly attributed to the acquisition and attempted use of functionally deficient software tools. The application of current E&V technology can alleviate many of these problems with respect to compilation systems, and to a lesser degree with other software tools. However, the application of E&V technology is not without its own problems.

First, *most software tools acquisition personnel are not aware of the available technology.* If they are aware, they are not sure how to leverage it during the acquisition process. This is a publicity and

education problem. Second, *application of E&V technology, such as the ACEC, is recommended for the technically proficient*. There are learning curves associated with understanding how to use the technology and interpret its results. Finally, today there are a significant number of individual organizations attempting to use E&V technology. *There is no current evidence that the organizations performing software tool evaluations are sharing their experiences and results*. Thus, different agencies could be evaluating the very same products.

For these reasons, it is recommended that the DoD identify an agency or agencies to (1) be responsible for the application of E&V technology, and (2) acquire or develop the expertise necessary to do so. This agency could be the same one selected to maintain and enhance existing E&V technology. This organization would also be responsible for proliferating E&V technology information throughout the software tool acquisition community and providing the community with the guidance necessary to exploit E&V technology during the acquisition process.

3. WORKING GROUP REPORTS

This section contains a brief history of each working group chartered within the E&V Team. Included in the reports is the purpose of each group, products delivered by each group, a general discussion of each group's activities, and specific recommendations made by each working group. These recommendations supplement those made by the E&V Team as a whole and presented in Section 4.

3.1 ADA COMPILER EVALUATION CAPABILITY WORKING GROUP (ACECWG)

3.1.1 ACECWG Purpose

The purpose of the ACECWG was to provide feedback to the ACEC contract monitor pertaining to (1) two versions of the ACEC software product and its documentation, and (2) plans for maintenance, enhancement, and use of the ACEC.

3.1.2 ACECWG Major Products

While the ACECWG did not produce a formal product, the ACEC was influenced by the comments and recommendations of the ACECWG. The ACEC is described in Section 2.4.1.

3.1.3 ACECWG Activities

The ACECWG had an important and beneficial impact on the ACEC software product and its documentation. The group played a central role in defining the scope of the Ada compiler evaluation problem and a taxonomy of evaluation issues against which the coverage of the ACEC could be measured. Major weaknesses in the coverage achieved by the ACEC were pointed out and drafts of the documentation were critiqued. When Version 1.0 of the software product was released, ACECWG members ran the tests and provided software trouble reports and justification for modifications. It is safe to say that the ACECWG provided the earliest and the most in-depth commentary on the test suite, its documentation, and its suitability for use. In particular, the ACECWG prioritized the ACEC 1.0 problem reports according to their severity and provided advice on the level of quality required for the ACEC before it should be considered suitable as a component for a Quality Testing Service.

While the group had no input into the original statement of work for ACEC Version 1.0, it did significantly influence the contents of Version 2.0. Additions to Version 2.0 included 300 new performance

tests as well as assessment capabilities for three new functional areas — diagnostics, the debugger, and the program library system. The group contributed even more to suggested enhancements and improvements to ACEC that will influence Version 3.0. In fact, there will be major revisions in Version 3.0 that will include adding compile time, capacity, and memory size tests, as well as addressing some of the critical usability issues associated with test organization and naming conventions, and simplification of the operating procedures. These usability issues must be addressed in order to give the maximum amount of information while reducing the amount of time required to learn and run the evaluation suite.

The ACECWG also provided considerable feedback on several iterations of a plan for an evaluation service based on the ACEC. This service has most recently been referred to as the Quality Testing Service. As a result of ACECWG and general E&V Team input, the plan was modified substantially. Originally the draft policy was modelled after the Ada Compiler Validation Capability (ACVC) and the Ada Validation Service and was called the Ada Compiler Evaluation Procedures and Guidelines (P&G) Version 1.0, dated 01 Mar 89. After much input from the E&V Team and others this became the Ada Compiler Performance Testing Service (PTS) Procedures, dated 15 Aug 89. After more extensive review and comment this became the Quality Testing Service (QTS) Procedures, dated 06 Oct 89. While not yet perfect, the latest version represents a very substantial improvement over the original effort and, in the opinion of the ACECWG, could serve as the basis for a DoD Ada compiler evaluation process.

3.1.4 ACECWG Recommendations

None beyond those presented in Section 4.

3.2 CAIS IMPLEMENTATION VALIDATION CAPABILITY WORKING GROUP (CIVCWG)

3.2.1 CIVCWG Purpose

The CIVCWG was responsible for examining and supporting validation of the CIVC products. Thus, the CIVCWG provided a forum for technical review and comment on the CAIS Implementation Validation Capability (CIVC) and CIVC2 contractual products for CAIS and for CAIS-A, respectively.

3.2.2 CIVCWG Major Products

While the CIVCWG did not produce a formal product, the CIVC, Versions 1 and 2, were influenced by the comments and recommendations of the CIVCWG. The CIVC is described in Section 2.4.2.

3.2.3 CIVCWG Activities

The CIVCWG's primary activity was that of providing technical input to the CIVC contractor to improve the quality and usability of the CIVC product. The comments, critiques, and recommendations were provided via regularly scheduled quarterly E&V Team meetings, contract-required Technical Interchange Meetings (TIM), and extensive use of the electronic mail facility on the MILNET. Several of the CIVCWG members participated in the standardization activities and reviews for both CAIS (DoD-STD-1938) and CAIS-A (MIL-STD-1838A) and are currently active in the standardization activity for the Portable Common Interface Set (PCIS). Consequently, the necessary expertise has been available to ensure the development of a usable and relevant validation capability for CAIS and CAIS-A. Additionally, the CIVCWG reviewed and commented on the methods and techniques being developed to achieve the validation capability. During early phases of the team's activity, this working group operated under the name of the CAIS Validation Capability Working Group (CVCWG).

3.2.4 CIVCWG Recommendations

3.2.4.1 The E&V technology development and maintenance efforts related to standards should be transferred to a Government funded organization, such as a Federally Funded Research Center (FFRC).

The CIVC2 contract activity continues until March 1992 and will continue to require technical review as well as continued funding. The full development of this validation capability will enhance the usability of implementations of the CAIS-A standard as well as the confidence of the users of the standard. Politically and economically, it may be more achievable to arrange for an existing FFRC (e.g., the SEI) to acquire the charter for E&V technology. Future enhancements of E&V technology should concentrate on supporting large software systems development, particularly with respect to the following issues: evaluating the interactions of multiple APSEs, evaluating and validating changing configurations of evolving APSEs, and evaluating and validating the integration of tools developed for use on, or tailored to, a particular project.

3.3 CLASSIFICATION WORKING GROUP (CLASSWG)

3.3.1 CLASSWG Purpose

The purpose of the CLASSWG was to provide feedback to the E&V Technical Support contract monitor on the E&V Reference System. This included feedback on the draft versions of the Reference Manual and Guidebook, as well as feedback on the plans for maintenance, enhancement, and use of the Reference System. Specifically, the CLASSWG was to serve as the focal point for analysis of the E&V Reference System, solicit information and recommendations regarding E&V technology, classify E&V technology for inclusion in the Reference System, aid in technology transition of the Reference System, delineate issues associated with evaluating APSEs when taken as a whole, and recommend new areas of investigation.

3.3.2 CLASSWG Major Products

While the CLASSWG did not produce a formal product, the E&V Reference System was influenced by the comments and recommendations of the CLASSWG. The E&V Reference System is described in Section 2.4.3. In addition to providing suggestions for ways to improve the E&V Reference System, the CLASSWG participated directly in drafting new sections of the documents, including some of the checklists and questionnaires which comprise the assessment technology found within the Guidebook.

3.3.3 CLASSWG Activities

All of the activities of the CLASSWG were devoted to making the E&V Reference System meet the needs of DoD and its contractors. Specifically, the CLASSWG reviewed drafts of the Reference System, identified areas where additional technology was needed, created new technology in the form of questionnaires and checklists, solicited the help of the E&V Team members with expertise in areas other than those of the CLASSWG, reviewed external sources of information to identify new technology to be summarized in the Reference System, created new entries and synopses, and continuously searched for new E&V technology during daily activities in their home organizations and elsewhere. During the early years of the team's activity an APSE Working Group (APSEWG) produced materials that influenced the classification schema which now provides a structure for the E&V Reference Manual.

3.3.4 CLASSWG Recommendations

3.3.4.1 Establish a review group of professionals with diverse backgrounds to support the continued enhancement of the E&V Reference System.

An effort such as that required to produce and enhance what is intended to be a comprehensive Reference System for E&V technology requires familiarity with advances and expertise in a wide range of topics. To date, the E&V Reference System has benefitted from the inputs and reviews of the CLASSWG and the E&V Team, as a whole. It will be very difficult to compensate for the loss of these resources with supplemental input from within a single corporation. Therefore, it is recommended that an external review group be established to support the continued enhancement of the E&V Reference System.

3.4 REQUIREMENTS WORKING GROUP (REQWG)

3.4.1 REQWG Purpose

The purpose of the REQWG was to identity requirements for the activities of the E&V Team and for APSE evaluation and validation. Specifically, this included maintaining the E&V Requirements Document; analyzing the requirements to determine adequacy, completeness, traceability, consistency, and feasibility; identifying issues which may impact the development of E&V technology; providing recommendations for the acquisition of E&V Tools and Aids; and preparing position papers addressing issues concerning E&V requirements.

3.4.2 REQWG Major Products

The major products of the REQWG included the Requirements Document [E&V Requirements 1987] and the Tools and Aids Document [E&V Tools and Aids 1990]. The Requirements Document is described in Section 2.3.1. The Tools and Aids Document is described in Section 2.3.5.

3.4.3 REQWG Activities

REQWG activities included defining requirements for the E&V Team and the E&V Project, periodically reviewing E&V efforts to determine whether or not requirements were being satisfied, defining future needs for E&V technology, periodically determining which team members were attending conferences so that E&V materials could be distributed, creating the E&Ving Newsletter - a newsletter about E&V technology updates, and identifying opportunities for E&V technology transition.

3.4.4 REQWG Recommendations

None beyond those presented in Section 4.

3.5 STANDARDS EVALUATION AND VALIDATION WORKING GROUP (SEVWG)

3.5.1 SEVWG Purpose

The purpose of the SEVWG was to provide a forum for discussions pertaining to the evaluation and validation of current, proposed, and future APSE related standards and their implementations. Included in the charter were the requirements to: (1) identify issues relating to validating conformance to an APSE related standard, and (2) suggest approaches for achieving conformance. The SEVWG was also concerned with all aspects of evaluating implementations of standards. Both technical and non-technical aspects of APSE standards were considered.

3.5.2 SEVWG Major Products

The major products of the SEVWG include the APSE Component Validation Procedures Document [CVP 1985], the Issues and Strategies for CAIS Evaluation and Validation document, [Issues 1987] and the Issues and Strategies for Evaluation and Validation of CAIS-A Implementations document [Issues 1990]. The APSE Component Validation Procedures Document is described in Section 2.3.2. The Issues and Strategies for CAIS Evaluation and Validation document is described in Section 2.3.3. The Issues and Strategies for Evaluation and Validation of CAIS-A Implementations document is described in Section 2.3.4.

3.5.3 SEVWG Activities

The SEVWG began as the Common APSE Interface Set Working Group (CAISWG), with a limited initial charter that included only the examination of issues concerning the validation of the CAIS interfaces. The E&V Team's CAISWG produced the APSE Component Validation Procedures Document in 1985. Realizing that several environment standards would evolve, the CAISWG changed its name to SEVWG to reflect a broader role in looking at various APSE standards. Although the SEVWG has considered and discussed other APSE standards, its products have focused on the CAIS. The CAIS-A is a design enhancement of DoD-STD-1838 and has been standardized as MIL-STD-1838A. It was developed by SofTech, San Diego under contract to the Naval Ocean Systems Center. In February 1990, the SEVWG released its Issues and Strategies for Evaluation and Validation of CAIS-A Implementations, an analysis of the validateability of CAIS-A.

3.5.4 SEVWG Recommendations

None beyond those presented in Section 4.

4. RECOMMENDATIONS

After seven years of research, development, evaluation, and lively debates, the E&V Team has settled on the following recommendations as being the most critical for action. The list of recommendations is summarized in Table 4-1. Some of the recommendations are meant to compensate for the anticipated absence of the team's involvement in future E&V-related activities. Some indicate actions required for the successful application of E&V technology on DoD programs. Many are just now becoming appropriate due to the development of technology by the E&V Project. Still others reflect areas in need of future enhancement. *It is the sincere desire of the E&V Team that the AJPO will carefully consider each of these recommendations, identify appropriate means of implementation, and work with related organizations to advance and enhance the technology and its use to the benefit of the DoD.* Our commitment to the technology should be evident given our ability to convince our home organizations that the voluntary support of this effort should be continued over a seven year period. It is hoped that the AJPO's actions will leverage our contributions and indicate an equal or greater commitment to the technology in the future.

4.1 RAISE PUBLIC AWARENESS OF E&V AND, AS A BROAD OBJECTIVE, ENCOURAGE USE OF APSE E&V TECHNOLOGY

- Support software process insertion activities
- Stress utilization of existing technology
- Support educational activities
- Provide incentives
- Incorporate into existing policies and standards.

Efforts to insert E&V technology into mainstream software development processes should be supported. Insertion of E&V technology requires: (1) Availability of the technology, (2) Availability of a skill base with respect to the application of the technology and (3) Perceived Value in the application of the technology. As discussed below, each of these items is within reach. Therefore, *it is recommended that specific major programs* (e.g., STARS, SDI, ATF) *be targeted for the first insertion of assessment technology in the procurement process.* As a secondary effort, it is recommended that major on-going programs develop a mechanism by which assessment technology is applied to determine the current quality of those programs and to identify areas for improvement.

Table 4-1 Summary of E&V Team Recommendations

1. Raise Public Awareness of E&V and, as a Broad Objective, Encourage Use of APSE E&V Technology
   - Support software process insertion activities
   - Stress utilization of existing technology
   - Support educational activities
   - Provide incentives
   - Incorporate into existing policies and standards.

2. Mandate Compiler Evaluations
   - Integrate compiler evaluation with procurements, not with the validation process
   - Require appropriate evaluations, considering project size, nature, and critical factors.

3. Create a Quality Testing Center of Expertise
   - Perform evaluations upon request and provide evaluation resources such as software, documentation, and guidelines.
   - Provide consulting services to projects, Government agencies, and contractors.

4. Continue Development of E&V Technology in Four Areas and Coordination with Related Activities
   - Enhance the APSE E&V Reference System and develop a hypertext version.
   - Enhance the Ada Compiler Evaluation Capability (ACEC).
   - Enhance the CAIS Implementation Validation Capability (CIVC) and transition to PCIS validation
   - Continue development of integrated APSE evaluation capability (structured experiments).

5. Promote Applicable APSE Standards
   - Promote standards for tool transportability, data interoperability, data representation, user interfaces, communications, Ada runtimes, etc.
   - Stress importance of such standards as a benefit to software maintenance organizations.

6. Identify an Appropriate Organization for APSE E&V Standards Activities; Develop, Manage, and Maintain E&V Test Suites Using A Unified Approach
   - Develop a single approach and encourage use of tools in developing suites.
   - Require test suite developers to deliver suites in a maintainable form, such that appropriate tools can be used.

7. Promote International Sharing of E&V Technology, But Avoid Joint Multinational Development of Assessor Products

Today, *a wide variety of APSE E&V technology is available for use*. Some of the existing capabilities were developed by the E&V Project (e.g., the ACEC); some were developed independent of this effort (e.g., the PIWG benchmarks). While the E&V Reference System is far from complete, it does contain and reference valuable E&V technology in many important areas. These include compilation system assessors, requirements and design tool assessors, and assessors that are applicable to all tools (e.g., cost, required configuration, and licensing issues questionnaires). Widespread use of these techniques will assist the Government and its contractors in selecting suitable tools and will improve the quality of tools produced by the vendors. This is particularly important in an environment in which increasing emphasis is being placed on buying more software off the shelf rather than building it from scratch. The E&V Reference System should be reviewed to determine what capabilities exist before efforts to develop new technology are initiated. Future developments should build upon material already reported in the Reference System, rather than replicate it.

The availability of software engineers with the skills needed to apply E&V technology and interpret the results can be improved by supporting an aggressive, formal effort to educate the technical public about the nature and availability of E&V technology. When providing E&V education, however, several key aspects must be considered. Defining the terminology of validation and evaluation by describing what they are, what they are not, how they differ, and how they relate to one another must be foremost. Further, the benefits of using the technology should be clearly discussed. Available E&V technology should also be presented and demonstrated. There are several avenues in existence today which should be used to support such E&V education. A significant resource is the Software Engineering Institute (SEI) which has already developed a software engineering curriculum. In addition, the ASEET, CRAC, and special educational briefings by the Services should be used as forums for improving public awareness of E&V technology. Special emphasis should be placed on educating DoD procurement personnel, as to what assessment technology is, what assessment tools exist, and how assessment technology can be applied to varying aspects of proposal or performance evaluations. Successful E&V education depends on the development and maintenance of appropriate presentation materials. To this end, a curriculum module on E&V technology should be developed and updated periodically. Such a module would provide a single formal package of materials which could be used throughout the industry for E&V education and information.

Perceived value can be increased by customers illustrating their commitment and enthusiasm via the employment of incentives for the use of E&V technology. The Ada programming language was designed, in part, to foster good software engineering practices. The use of APSE E&V technology should

be one of those "good" practices. It is believed that the application of E&V (assessment) technology will provide a dramatic reduction in acquisition/maintenance costs. Therefore, contract incentive fees should be employed to ensure that E&V receives the management attention required to accomplish the integration of the technology into existing processes. Another type of incentive would encourage the application of assessment technology prior to contract award. When requests for proposal are created by the DoD, they should specify the assessment technology data that must be submitted with the contractor's proposal for use as technical evaluation criteria and/or contract award factors. This assessment data would then be used as feasibility or "goodness" indicators when the proposal is being technically evaluated.

Finally, *a high-level policy encouraging the use and continued development of E&V products should be implemented throughout the DoD*. Upper echelon support is critical for continued emphasis within the Services and other DoD agencies. Strong guidance, coupled with other incentives, is necessary to incorporate E&V technology into common practice. Existing standards and directives should include instructions for E&V technology use. For example, the Software Development Plan required by DoD-STD-2167A should be modified to require developers to describe their planned use of E&V technology. Industry must be encouraged to incorporate this technology into the early phases of their software development processes. The exploitation of existing policies and standards can be an avenue by which to accomplish this goal.

4.2 MANDATE COMPILER EVALUATIONS

- Integrate compiler evaluation with procurements, not with the validation process
- Require appropriate evaluations, considering project size, nature, and critical factors.

When the DoD developed the Ada language, it also developed a policy for the validation of language implementations against the standard. However, we have all come to realize that the validation of a compiler does not necessarily mean that it is fit for use on a specific project. Large Ada software development projects, if well managed, would perform compiler evaluations at different points in the life cycle for different reasons. For example, early evaluations would support the compiler/vendor selection process. Later evaluations are appropriate when the actual target configuration characteristics and settings have changed; they serve to keep the development team (and maintenance team) fully aware of the current system's strengths and weaknesses. Such evaluations are likely to make use of the ACEC test suite and other benchmark tests tailored for the specific application, as well as additional qualitative

assessments based on checklists and questionnaires available via the E&V Reference System. The details of such evaluations will vary, however, depending on each project's critical success factors, size, application domain, etc.

A policy should be established requiring that, for each procurement, the critical compilation system-related issues be determined and candidate compilers evaluated. Program personnel should be required to identify the risk drivers that the compiler presents to the program and structure the evaluation process to minimize the risk. Program offices should also be required to document the approach used to select a compiler to minimize procurement risk.

4.3 CREATE A QUALITY TESTING CENTER OF EXPERTISE

- Perform evaluations upon request and provide evaluation resources such as software, documentation, and guidelines.
- Provide consulting services to projects, Government agencies, and contractors.

The process of evaluating APSEs as a whole or individual components of an APSE can be quite complex. Each APSE component provides different functionality that may be required to interact with other APSE components in a variety of ways. This may be the subject of evaluation. In addition to the functionality provided, the suitability of individual tools for use on a major development may be of interest. The skills required to use available APSE E&V technology also vary based on the subject and process of the evaluation. In some cases, it may be sufficient to complete a checklist describing functional capabilities. In other cases, the execution of a test suite such as the ACEC and the detailed analysis of its results may be required to answer the questions of interest. Since procurements of APSE components will be based on the results of evaluations, it is absolutely crucial that the evaluation approach employed is appropriate, and the analysis is correct for the circumstances involved.

Due to the variety and complexity of both the components requiring evaluation and the technology available to perform the evaluations, it is recommended that a Quality Testing Center of Expertise be established. It should be a resource to the DoD that could (1) provide evaluation technology to organizations interested in performing evaluations, (2) help projects, Government agencies, or contractors determine what evaluations are necessary and what technology is applicable, (3) evaluate the process and results of evaluations conducted by others (for example, as part of a procurement activity), or (4) perform evaluations in house, on request, (providing recommendations to its customers concerning APSE technologies appropriate for use on a given project).

4.4 CONTINUE DEVELOPMENT OF E&V TECHNOLOGY IN FOUR AREAS AND COORDINATION WITH RELATED ACTIVITIES

- Enhance the APSE E&V Reference System and develop a hypertext version.
- Enhance the Ada Compiler Evaluation Capability (ACEC).
- Enhance the CAIS Implementation Validation Capability (CIVC) and transition to PCIS validation.
- Continue development of integrated APSE evaluation capability (structured experiments).

Existing evaluation and validation technology is still incomplete and immature. Contractual efforts to develop and refine the technology should be continued. Some of the efforts sponsored by the E&V Project have been through several iterations, while others are in their early stages. Still, *the need for E&V technology is largely unfulfilled.* As a result, Government programs are using untried and untested tools which are, in many instances, responsible for costly overruns and schedule delays. The E&V technology that has been developed to date is helpful, but in need of further refinement. New functionality must be added and user interfaces improved. *For a relatively small incremental investment in existing evaluation and validation technology for APSE tools, considerable expenditures over the life cycles of all software programs can be eliminated.* Among the products still under development by the E&V Project are the E&V Reference System, the ACEC, the CIVC, and structured experiments designed to evaluate integrated APSE capabilities. Failure to follow up on these efforts and carry them through to a successful conclusion would be a tremendous waste of potentially useful technology.

The E&V Reference System consists of two coordinated documents: the E&V Reference Manual [E&V RM 1989] and the E&V Guidebook [E&V GB 1989]. These documents are a valuable source of information that describe the current state of E&V technology, contain some of the technology (e.g., checklists and questionnaires) within their covers, provide many summaries and references to detailed descriptions of specific instances (e.g., test suites) of the technology, provide a framework for understanding environments and their assessment, and provide definitions of the terminology used in all of the above. The Reference System has been updated annually since 1987. *Since E&V technology is rapidly growing and improving, it is necessary to continue to update the Reference System and to make it readily and broadly available.* In particular, future evolution of the E&V Reference System should be directed at issues such as integrated environments, environment infrastructures, and standards validation and evaluation. There is no "silver bullet" [Brooks 1987] for solving the software crisis. The solution requires more than a single tool or development language such as Ada. Integration or cooperation among

tools in an environment is, however, a potentially significant contributor to future improvements. As the emphasis of tool and environment builders shifts toward integration issues, the emphasis of assessment technology users and builders should shift in the same direction. By recognizing the shift in emphasis early, the E&V Reference System can help accelerate the movement toward integrated environments by educating the user community on the important E&V issues. The usefulness of the E&V Reference System can be further enhanced by making electronic versions of the system widely available through repositories such as the STARS repository and developing an on-line version with hypertext features.

To date, two versions of the ACEC have been released to the public. While the product is helpful in its current form, there are a number of ways to make it more useful. The first version of the ACEC stressed performance of the generated code and the Ada runtime system. The second version of the ACEC added more performance tests; provided assessors for the program library system, diagnostics, and the debugger; and refined its analysis tools. Plans exist for a third version that will increase the attention paid to compile time performance, capacity testing, and, especially, usability issues. Without these improvements, the ACEC will be considered to be incomplete and hard to use. Moreover, the evaluation suite must be modified to address the changes to the Language Reference Manual [DoD 1983] anticipated as a result of the Ada9X project. *The ACEC should be the cornerstone for the evaluation of Ada compilation systems. To be viable in this role, it must be supported over the long term.*

The CIVC program has successfully applied new technologies to product development in support of the validation testing process. Information modeling of test coverage design and assessment for validation testing; hypermedia implementation of test requirements, test designs, and their traceability relationships; and application of automated methods to test selection, prioritization, and code generation have advanced the CIVC validation process far beyond its initial capabilities. These validation development tools and products have been designed to accommodate future validation needs (i.e., PCIS), and additional funding is crucial in order to continue the development of a superior validation capability. *Considering that (1) the automated development tools are prototype systems and (2) new hypertext systems with greater functionality are being released at an explosive rate, further development efforts have been identified to evolve the existing CIVC into a state-of-the-art, production quality validation system.*

Most of the E&V technology developed to date is oriented toward the assessment of individual tools, with emphasis on compiler validation and evaluation (e.g., ACVC, ACEC, AES). Now that Ada compilers are maturing, attention will increasingly turn to other needs, such as the evaluation of front-end CASE tools, test tools, and whole APSEs. *An especially important need is the capability to evaluate APSEs considered as integrated systems that influence the productivity of whole teams working*

throughout the entire project life cycle. A promising start has been made in creating a family of structured experiments that are designed to provide this kind of capability. This effort should be continued and expanded.

The coordination of E & V technology developments with related activities should be continued and expanded. There are at least three kinds of Government-sponsored activities that can be enhanced by strong coordination with E&V activities. First, R&D efforts aimed at developing better and more integrated tools, environments, and repositories (e.g., STARS) can benefit from careful consideration of the techniques employed to evaluate the performance and quality of these elements. Second, major programs which must evaluate and select environment components (e.g., the SDI, the NASA Space Station) can benefit from, and contribute to, the latest advances in evaluation technology. Their environment selections will represent major investments with far-reaching consequences. Third, activities related to the definition of, or mandated use of, standards (e.g., CAIS-A) can benefit from careful consideration of validation technology and the problem of determining conformance to a standard. To date, the E&V Project has devoted a significant amount of attention to coordination with related efforts. Numerous briefings and birds-of-a-feather sessions have been held at Ada-related conferences. The existence of the E&V Team was, in itself, another major commitment to coordination. Members of the team acted as ambassadors for E&V technology in their home organizations and in all of the related activities in which they were involved. In addition, they represented the voice of reason to the E&V technology development efforts, ensuring that the end products would be appropriate for its intended user community. It will be very difficult to compensate for the loss of 30 ambassadors. As a minimum, managers of R&D efforts, major programs, and standards activities should be required to report regularly on their use and knowledge of E&V technology. Similarly, managers of E&V technology developments should be required to work directly with selected major programs to ensure realism and appropriateness of ongoing work.

4.5 PROMOTE APPLICABLE APSE STANDARDS

- Promote standards for tool transportability, data interoperability, data representation, user interfaces, communications, Ada runtimes, etc.
- Stress importance of such standards as a benefit to software maintenance organizations.

Important aspects of tool reusability and maintainability can only be achieved through interface standardization. Standards should be developed in three areas: tool interfaces, run time environment (RTE) interfaces, and data interchange protocols.

Tool transportability interfaces such as CAIS-A and PCIS are currently under development or are in use. Such standards will eventually result in lower maintenance costs of Government-owned applications. The increased portability of tools will reduce personnel training costs associated with tool usage and a wider potential market will motivate vendors to develop better and more effective tools.

Ada RTEs vary significantly in capability and interfaces. Standardization will facilitate portability of applications that require access to the low level features of an Ada implementation. In particular, difficult categories of applications such as "hard real time" applications, will receive significant benefits from RTE standardization. The activities and reports generated by the Ada Run Time Environments Working Group (ARTEWG) within SIGAda provide a valuable foundation for standards development in this area.

Data interchange protocols provide the capability to design new, highly specialized, tools to interface with existing toolsets and existing maintenance databases. These protocols are essential to long term maintenance activities because, with well documented interchange protocols, new tools can be created to support systems whose developers are no longer in the marketplace. Additionally, as vendors leave the market or reduce support on older toolsets (APSEs) new vendors can target the same market niche and customer base with new tools. They can provide equivalent or better functionality because the data protocols will be well documented and standardized.

This area of activity is not yet well supported in the Ada community. Consequently, it would be appropriate to encourage an FFRC, such as the SEI, to initiate research in this area and to act as an advocacy group for the standardization of data interchange protocols.

4.6 IDENTIFY AN APPROPRIATE ORGANIZATION FOR E&V OF APSE STANDARDS ACTIVITIES; DEVELOP, MANAGE, AND MAINTAIN E&V TEST SUITES USING A UNIFIED APPROACH

- Develop a single approach and encourage use of tools in developing suites.
- Require test suite developers to deliver suites in a maintainable form, such that appropriate tools can be used.

APSE standards should be viewed as inseparable from the mechanisms required to assess conformance and quality of implementations, and appropriateness for use. The AJPO should continue efforts to provide evaluation and validation mechanisms for existing Ada and APSE standards. The early

introduction of E&V technology into new standards efforts will have the following effects: increase the confidence of users in the new standards, avoid design decisions that inhibit evaluation and validation, and reduce the time required to achieve usable standards by developing assessment technology in parallel with the standards.

An organization should be formed for developing, maintaining, and promulgating E&V technology for APSE standards. The organization should develop a single approach for test suite development, management, maintenance, and use, which accommodates all aspects of evaluation and validation suites.

A number of future standards would benefit from the technology developed as part of the CIVC. Specifically, E&V technology should be used to facilitate the PCIS standardization activity. The PCIS is a standard being developed in conjunction with our NATO allies that combines the best features of both CAIS-A and the equivalent European standard (PCTE+). The PCIS activity is planning to achieve standardization in mid-1994. The technology developed for the CIVC2 contract would facilitate validation and conformance testing for the PCIS standard and should be transitioned to this forthcoming standards activity. This technology involves actual tests, analysis tools, and a methodology for development that includes:

- Information Models — These models facilitate the design and assessment of the coverage of validation test suites. They also assist in the prioritization of test objectives and leverage testing effort more effectively. A framework for management of test suites is also provided by information models.
- Test Selection and Prioritization — Test selection and prioritization involves the development of a strategy to select areas of a standard for initial test development and other areas for later test development. This prioritization activity is difficult and error prone if done in an ad hoc manner. The CIVC effort has developed methods for the analysis of systems with information models that result in intelligent selection of tests to develop for validation suites. Coverage by a test suite is increased by these methods, and the development efforts are consequently more cost effective.
- Test Case Generation — Semantic and behavioral models of interface sets may enable the automated generation of test cases. Prototypes already developed by the CIVC contractor indicate that this approach is feasible. An automated approach would enable a much greater number of test cases to be generated compared to the amount produced by a manual coding method.
- Hypermedia Traceability Systems — The CIVC effort has developed hypermedia-based systems for interactive presentation of test suite traceability. These systems significantly increase users' understanding of the derivation of software products.

In less than ten years, the ACVC has more than tripled in size, in response to the need to test products for conformance to the language standard. This fact underscores the need for validation capabilities

and indicates the importance of maintainability to decreasing the cost of such a set of tests. A significant portion of the effort to develop a suite should be devoted to easing enhancement. In cases where test suites are developed using alternate approaches, they should be delivered in a form such that the standard maintenance process can be used to maintain and enhance them.

Finally, multiple implementations of a standard create a situation where selections should be made using results of evaluation activities. Although there may never be a large number of competing implementations of some APSE standards, evaluation data is important for determining the suitability of an implementation for a given application. Therefore, it is recommended that efforts to create evaluation capabilities for standardized APSE interfaces be initiated.

4.7 PROMOTE INTERNATIONAL SHARING OF E&V TECHNOLOGY, BUT AVOID JOINT MULTINATIONAL DEVELOPMENT OF ASSESSOR PRODUCTS

Sharing of technology internationally should be encouraged to the maximum extent possible to avoid duplication of effort and to promote cooperation between nations. Evaluation and validation technology should be considered less sensitive as a technology than other software systems, such as actual military applications or APSE tools used to build military applications. The ACEC is basically the same type of technology as the ACVC, so any difference in the export controls placed on these two products is both confusing and counterproductive. Further, making the suite(s) available electronically would enhance the user community's ability, both at home and abroad, to access and use the most current suite in the most timely manner. *Although the practice of international development of standards is well established and the international sharing of E&V technology should be promoted, joint international development of E&V technology is neither cost effective nor warranted.* In fact, the logistical, political, and language barriers argue strongly against joint development of E&V technology.

5. CONCLUSION

Much progress has been made in the area of Evaluation and Validation since the E&V Team was established in 1983. At its inception, this was virtually an unexplored field of study. Now, a significant amount of usable technology is available. However, there is still much work to be done. As APSE components mature, the areas of concern change. This results in the need for new types of E&V technology to address the new critical issues. The E&V Team has done its best to make sure that existing E&V technology is both suitable and effective for application on today's programs. It has also tried to identify the needs of the future. *E&V Project accomplishments provide an excellent starting point for continued development of APSE E&V technology.*

APPENDIX A
LIST OF ACRONYMS

ACEC	Ada Compiler Evaluation Capability
ACECWG	ACEC Working Group
ACM	Association for Computing Machinery
ACVC	Ada Compiler Validation Capability
AES	Ada Evaluation System (United Kingdom product)
AFWAL	Air Force Wright Aeronautical Laboratories (later WRDC, now WL)
AJPO	Ada Joint Program Office
APSE	Ada Programming Support Environment
APSEWG	APSE Working Group (preceeded CLASSWG)
ARTEWEG	Ada Run Time Environments Working Group (of SIGAda)
ASEET	Ada Software Engineering Education and Training
ATF	Advanced Tactical Fighter
AVO	Ada Validation Office
CAIS	Common APSE Interface Set
CAIS–A	CAIS (Version A)
CAISWG	CAIS Working Group (preceeded SEVWG)
CASE	Computer Aided Software Engineering
CIVC, CIVC1	CAIS Implementation Validation Capability
CIVC2	CIVC for CAIS-A
CIVCWG	CIVC Working Group
CLASSWG	Classification Working Group
CRAC	Computer Resources Acquisition Course
CVCWG	CAIS Validation Capabilities Working Group (early CIVCWG)
DoD	Department of Defense
DR	Distinguished Reviewer
E&V	Evaluation and Validation
FFRC	Federally Funded Research Center
KAPSE	Kernel APSE
KIT	KAPSE Interface Team

NATO	North Atlantic Treaty Organization
PCIS	Portable Common Interface Set
PCTE+	Portable Common Tool Environment
PIWG	Performance Issues Working Group (of SIGAda)
PTS	Performance Testing Service
PUBWG	Publicity Working Group
P&G	Procedures and Guidelines
QTS	Quality Testing Service
REQWG	Requirements Working Group
R&D	Research and Development
RFP	Request for Proposal
RTE	Run Time Environment
SDI	Strategic Defense Initiative
SEI	Software Engineering Institute
SEVWG	Standards Evaluation and Validation Working Group
SIGAda	Special Interest Group: Ada (of the ACM)
STARS	Software Technology for Adaptable Reliable Systems
TASC	The Analytic Sciences Corporation
USAF	United States Air Force
VDD	Version Description Document
WG	Working Group
WL	Wright Laboratory (formerly WRDC)
WRDC	Wright Research and Development Center (formerly AFWAL, now WL)
WPAFB	Wright Patterson Air Force Base

APPENDIX B
E&V TEAM PARTICIPANTS

The following list was culled from E&V Team Public Reports and Meeting Minutes. Names of guest speakers and those who participated only briefly have been omitted. Everyone who participated in any way, however briefly, is thanked for their support and we apologize to any significant contributors whose names were inadvertently omitted. The names marked with asterisks are those who participated significantly during the final phase and helped formulate the team recommendations given in Section 4.

NAME	ORGANIZATION
*Abraham, Rebecca Capt.	WRDC/FIOC, WPAFB
*Adams, Karyl	c.j. kemp systems
*Ashby, Sam	Boeing Military Airplane
Anderson, Christine	AFATL, Eglin AFB
Bailey, Betsy Kruesi	Institute for Defense Analyses
*Brashear, Philip	CTA Incorporated
Brookshire, Jerry	Texas Instruments
*Burlakoff, Mike	SW Missouri State University
Burns, Greg	GTE/Government Systems
Burton, Dan	ESD/ALL, Hanscom AFB
Camp, John	WRDC/AAAF-2, WPAFB
Castor, Virginia	AJPO, Pentagon
*Chilson, Lynn	SofTech
Chitwood, Georgeanne	ASD/ADOL, WPAFB
*Clark, Peter	TASC
*Crawford, Bard	TASC
Deese, Albert Capt.	ASD/SIOL WPAFB
Dobbs, Paul	General Dynamics
*Eilers, Dan	Irvine Compiler Corp.
Elderhorst, Linda	Sys. Eng. Test Direct. Patuxent River, MD
Estes, Nelson	ASD/AFALC/AXTS, WPAFB
Facemire, Jeff	SofTech
Fainter, Robert	Arizona State University
Fanning, Shawn	SofTech
*Ferguson, Clarence "Jay"	National Security Agency
Fleming, Richard	The Aerospace Corp.

NAME	ORGANIZATION
*Foidl, Jack	TRW, Systems Division
*Francl, Fred	Sonicraft, Inc.
Fritz, Robert	Computer Sciences Corp.
*Gicca, Greg	Sanders
Gilroy, Kathleen	Software Productivity Solutions
Gralia, Mars	APL, Johns Hopkins University
*Gutzmann, Kurt	SofTech
*Hackett, Kevin	SofTech
Hammons, Charles	Texas Instruments
Hanna, Bruce Capt.	WRDC/AAAF–2, WPAFB
Harto, Debra	AFATL/DLCM, Eglin AFB
*Hazle, Marlene	MITRE
Henne, Marlow	Harris Corp.
Holmes, Tracy	GTE Government Systems
Humphrey, Terry	Johnson Space Center
*Impicciche, Alan	Naval Avionics Center
*Jennings, Donald	OC–ALC/MMECO, Tinker AFB
*Kean, Elizabeth	RADC/COEE, Griffiss AFB
Kirkbride, Kathy	Oneida Resources
Kirkpatrick, James Lt.	AFALC/PTEC, WPAFB
Kopp, Allan Maj.	AJPO, Pentagon
Kramer, Jack	Institute for Defense Analyses
LaPointe, Mike Lt	AD/ENE, Eglin AFB
*Lawlis, Patricia Maj.	AFIT, WPAFB
*Leavitt, Thomas	Boenig Military Airplane
Leavitt, Randal	PRIOR Data Science
LeGrand, Sue	SofTech
*Lindquist, Tim	Arizona State University
Long, R. Lt.	WRDC/AAAF–2, WPAFB
*Maher, Patrick	Motorola GEG
Mark, Donald	RADC/COEE, Griffiss AFB
Marmelstein, Robert Lt.	WRDC/AAAF–2, WPAFB
*Martin, Ronnie	Purdue University
McBride, John	SofTech

NAME	ORGANIZATION
* McKee, Gary	MeKee Consulting
Meirink, Michael	Unisys
Miller, John	SM–ALC/MMEHD, McClellan AFB
Mills, Michael	ASD–AFALC/AXTS, WPAFB
* Mulholland, Sandi	Rockwell International
Mumm, Hans	Naval Ocean Systems Center
Munck, Robert	Unisys
Myers, Philip LCDR	AJPO, Pentagon
Oberndorf, Patricia	Naval Ocean Systems Center
Olson, Douglas Lt.	HQ AFCMD/SID, Kirtland AFB
Pickart, Bruce Capt.	HQ AFOTEC/LG5S
Probert, Tom	Institute for Defense Analyses
Reddan, John	SYSCON Corporation
Reilly, Paul	Data General Corporation
* Remkes, David	SofTech
Rhoads, Barbara	Oneida Resources
Rhoden, Victoria Capt.	ASD/TASE, WPAFB
Rohrer, Amos	EG&G
Romanowski, Helen	Rockwell International
Sabota, Darlene Lt.	AFWAL–FIGRB, WPAFB
Sandborgh, Raymond	Unisys
Schaar, Brian	AJPO, Pentagon
Stacey, Christine	GTE Government Systems
Stanton, John	AJPO, Pentagon
* Stiles, Lloyd	FCDSSA, San Diego
* Szymanski, Raymond	WL/AAAF–3, WPAFB
Taylor, Guy	FCDSSA, Dam Neck, VA
* Terrell, Kermit	Boeing Military Airplane
* Thomas, Jerry	Naval Ocean Systems Center
Tompkins, Mary Ann	Lockheed Missiles & Space Co.
* Weiderman, Nelson	Software Engineering Institute
Williamson, James	WRDC/AAAF–2, WPAFB
* Wills, Betty	CCSO/XPTB, Tinker AFB
Witt, Donald	AFIT/EN, WPAFB

APPENDIX C
REFERENCES

[ACEC 1990] "Ada Compiler Evaluation Capability (ACEC) Technical Operating Report (TOR) Reader's Guide," Air Force Wright Research and Development Center, D500-1247-1, May 1990.

[ACEC 1990a] "Ada Compiler Evaluation Capability (ACEC) Technical Operating Report (TOR) User's Guide," Air Force Wright Research and Development Center, D500-12470-1, May 1990.

[ACEC 1990b] "Ada Compiler Evaluation Capability (ACEC) Technical Operating Report (TOR) Version Description Document," Air Force Wright Research and Development Center, D500-12472-1, May 1990.

[Brooks 1987] Brooks, F.P. "No Silver Bullet — Essence and Accidents of Software Engineering," Computer, pp. 10-19, April 1987.

[CIVC 1989]"CIVC Implementor's Guide," SofTech, Inc. CIVC-FINL-19-1, 16 October 1989.

[CIVC 1990] "CIVC1 Framework," SofTech, Inc. CVC-VREL-2/1-01, 1 March 1990.

[CIVC 1990a] "Test Report Reader's Guide with Appendix 1 — *Operator's Guide*," SofTech, Inc. CIVIL-FINL-020-02, 19 March 1990.

[CIVC 1990b] "Beta Test Operator's Guide," SofTech, Inc., CIVC-FNL-20-03, 18 July 1990.

[CVP 1985] "Component Validation Procedures (CVP) Document," APSE E&V Team CAISWG, 1 December 1985.

[DoD 1983] ANSI/MIL-STD-1815A-1983, "Reference Manual for the Ada Programming Language," U.S. Department of Defense, 17 February 1983, DTIC Number AD A131 511.

[DoD 1986] DoD-STD-1838, "Common APSE Interface Set (CAIS)," U.S. Department of Defense, 9 October 1986, DTIC Number AD A157 589.

[DoD 1988] DoD-STD-2167A, "Defense System Software Development," U.S. Department of Defense, 29 February 1988.

[DoD 1989] MIL-STD-1838A, "Common APSE Interface Set, Revision A," U.S. Department of Defense, April 19898, DTIC Number AD A157 589.

[E&V GB 1989] "E&V Guidebook, Version 2.0," Wright Research and Development Center, 30 September 1989, DTIC Number AD A214 166.

[E&V Report 1984] Castor, V., "Evaluation and Validation (E&V) Team Public Report, Volume 1," Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, 30 November 1984, DTIC Number AD A153 609.

[E&V Report 1985] Szymanski, R., "Evaluation and Validation (E&V) Team Public Report, Volume II," Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, November 1985, DTIC Number AD A172 343.

[E&V Report 1987] Szymanski, R., "Evaluation and Validation (E&V) Team Public Report, Volume III," Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, September 1987, DTIC Number AD A196 164.

[E&V Report 1989] Szymanski, R., "Evaluation and Validation (E&V) Team Public Report, Volume IV," Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, January 1989, DTIC Number AD A206 394.

[E&V Report 1990] Szymanski, R., "Evaluation and Validation (E&V) Team Public Report, Volume V," Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, December 1990, DTIC Number to be assigned.

[E&V RM 1989] "E&V Reference Manual, Version 2.0," Wright Research and Development Center, 30 September 1989, DTIC Number AD A214 167.

[E&V Requirements 1984] "E&V Requirements Document," REQWG, included in [E&V Report 1984].

[E&V Requirements 1987] "E&V Requirements Document, Revised," REQWG, included in [E&V Report 1987].

[E&V Tools and Aids 1990] "E&V Tools and Aids Document," REQWG, included in [E&V Report 1990].

[E&V Workshop 1984] V.L. Castor, et al, "Ada Programming Support Environment (APSE) Evaluation and Validation (E&V) Workshop Report," Institute for Defense Analysis, December 1984, DTIC Number AD A156 667.

[Issues 1987] "Issues and Strategies for CAIS Evaluation and Validation, Version 1.0," APSE E&V Team SEVWG, September 1987, in [E&V Report 1987].

[Issues 1990] "Issues and Strategies for Evaluation and Validation of CAIS-A Implementations," based on April 6, 1989 MIL-STD-1838-A, APSE E&V Team SEVWG, February 1990.